



## Temporal Variations in Stratospheric Chlorine Monoxide from the Aura Microwave Limb Sounder

L. Froidevaux <sup>(1)</sup>, D. Kinnison <sup>(2)</sup>, M. L. Santee <sup>(1)</sup>,

N. J. Livesey <sup>(1)</sup>, W. G. Read <sup>(1)</sup>, and R. A. Fuller <sup>(1)</sup>

*<sup>(1)</sup>Jet Propulsion Laboratory, Caltech, Pasadena, CA, USA*

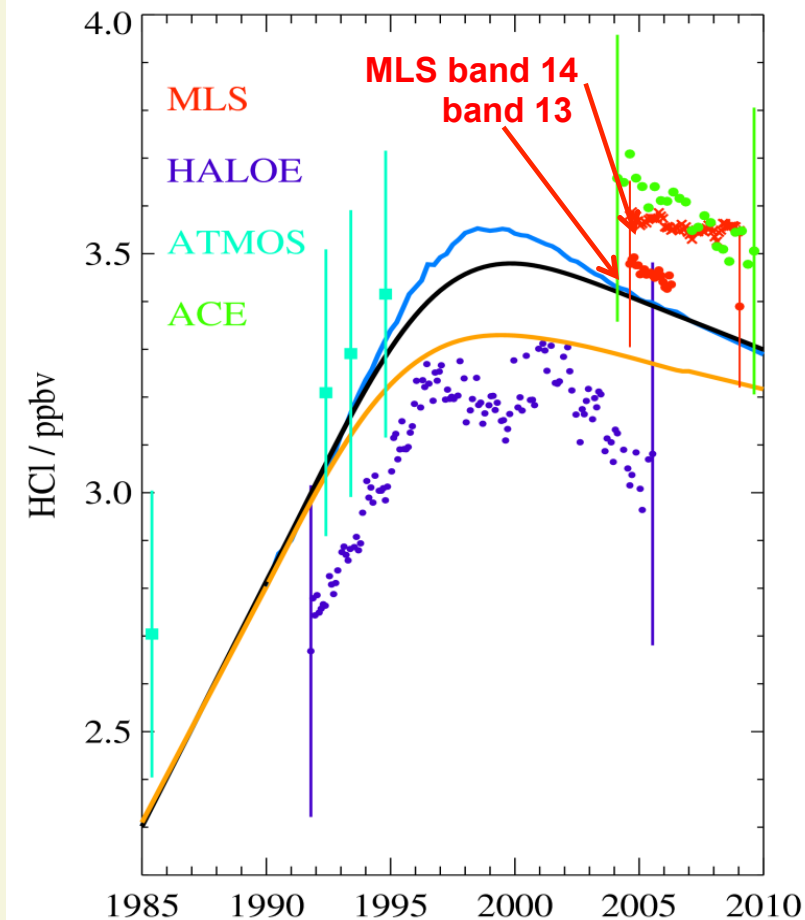
*<sup>(2)</sup>National Center for Atmospheric Research, Boulder, CO, USA*

**Credits:** teams for WACCM4 model runs and GEOS-5 analyses

***Aura Science Team Meeting, FMI, Helsinki, Finland, Sep. 13-15, 2011***

# Overview and Goals

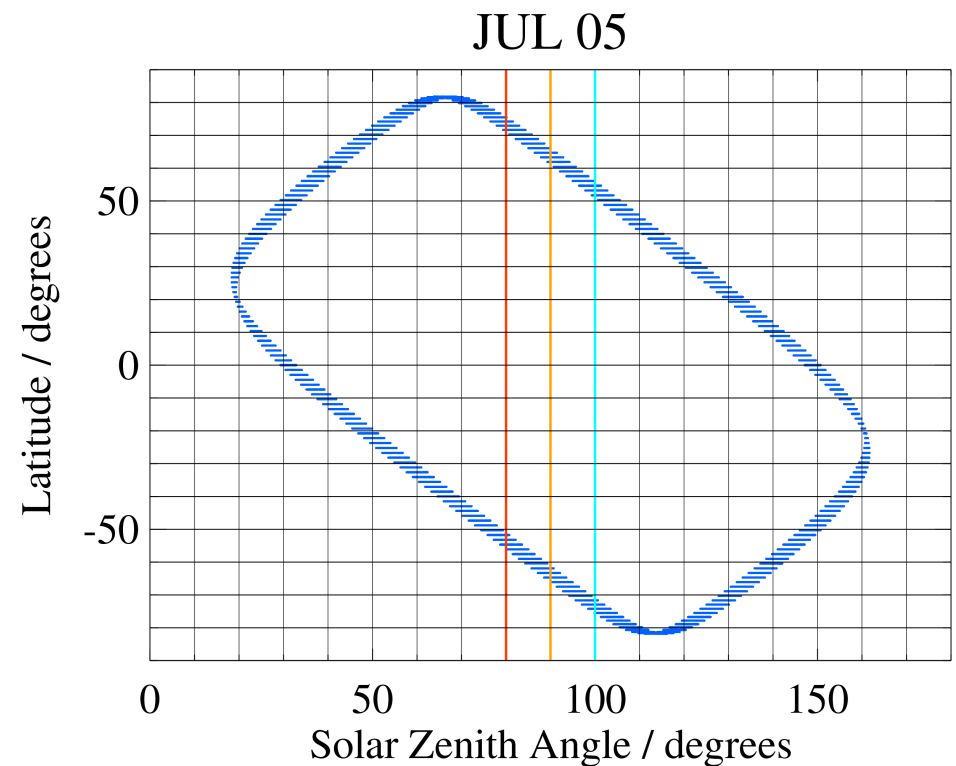
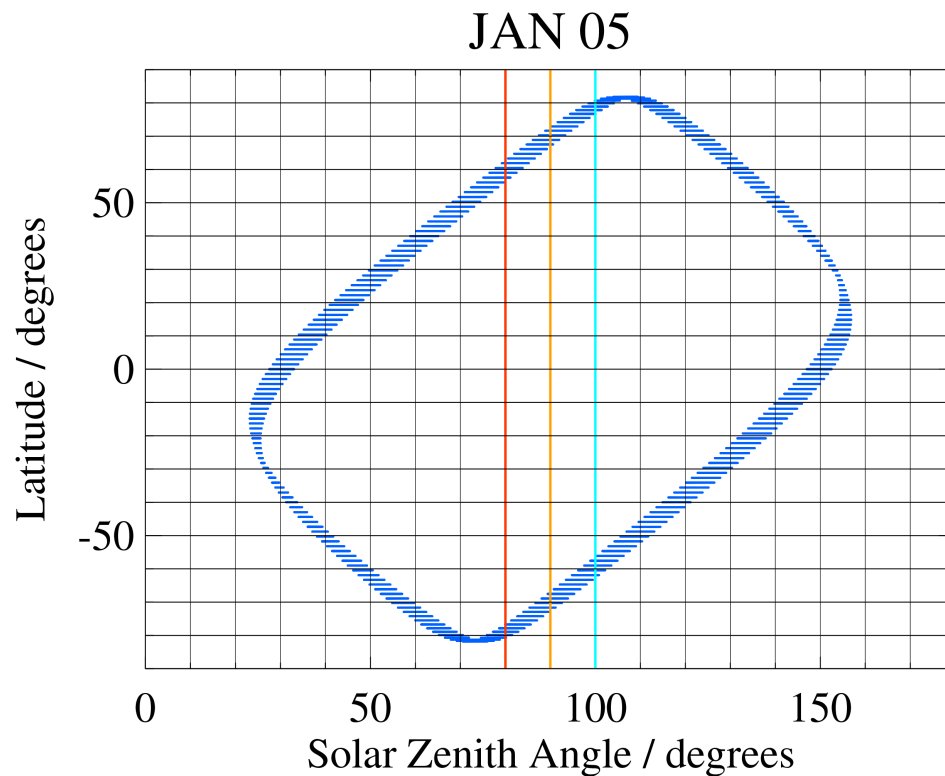
- What are the long-term changes in upper stratospheric chlorine?
  - > HCl trend results from Aura MLS are less robust after band 13 hardware-related issue (→ sparse B13 data after 2006)
  - MLS band 14 gives continuous daily HCl, but unsuitable for small trend detection (upper strat).
- Here, we show preliminary results on the “long-term” (6-7 yrs only...) behavior of daytime ClO from Aura MLS in the mid- to upper stratosphere
  - and compare with SD-WACCM4/GEOS-5
- ClO characteristics (mid-to upper strat.):
  - ~3500 strat. profiles daily (day and night)
  - Vertical resolution ~ 3.5 km
  - Precision (single profile) ~ 0.1 ppbv
  - Accuracy (sys. uncert.) ~10-15% (~0.05 ppbv)
  - > see *Santee et al.* [2008] for v2.2 validation
  - + v3.3 update in *Livesey et al.* [2011, MLS v3.3 Level 2 Data Quality and Description Document ]



## HCl trends (near 0.5 hPa)

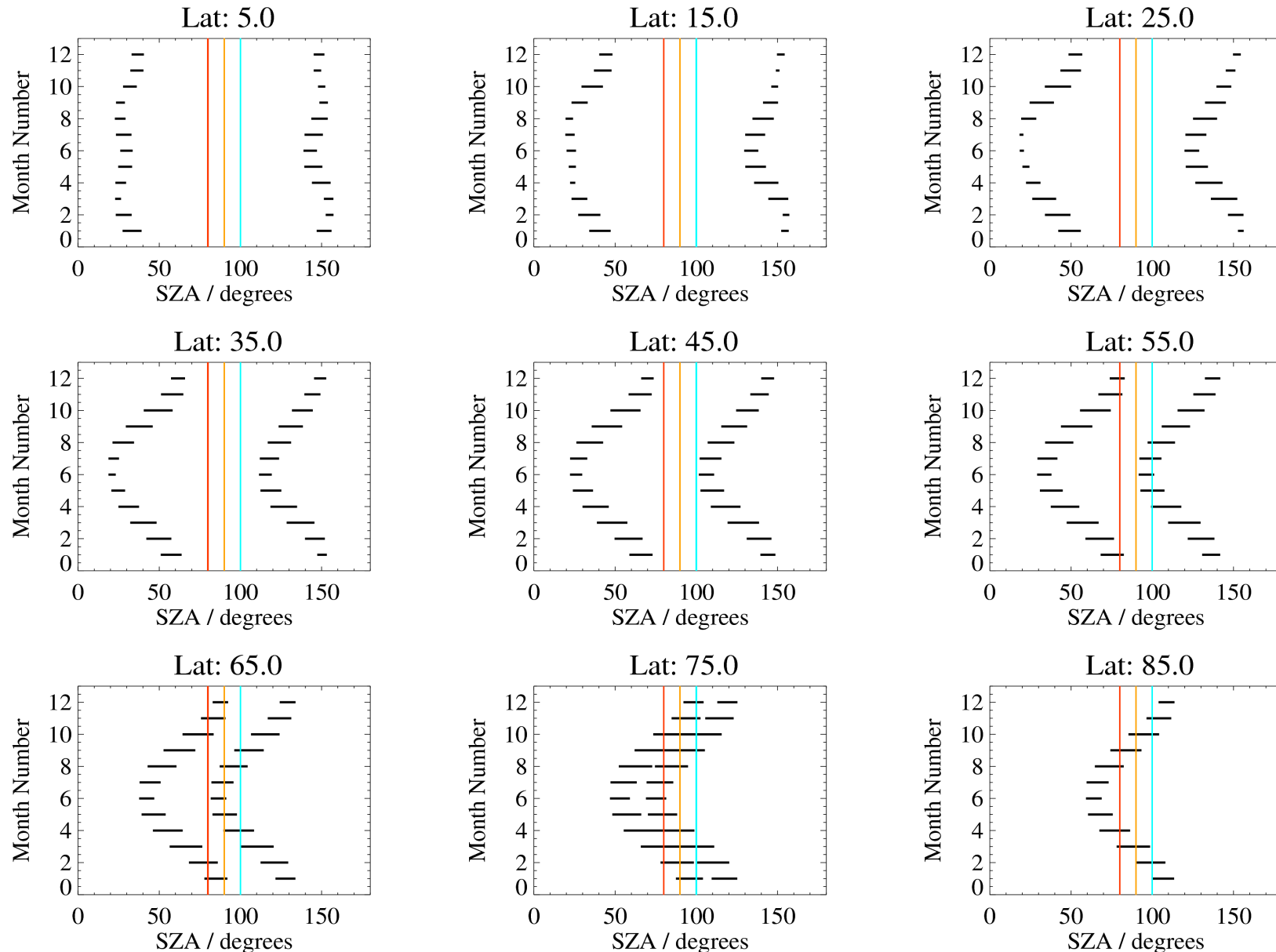
various datasets & expectations (curves)  
[updated from *Froidevaux et al.*, 2006]

# Solar Zenith Angle (SZA) variation in MLS coverage

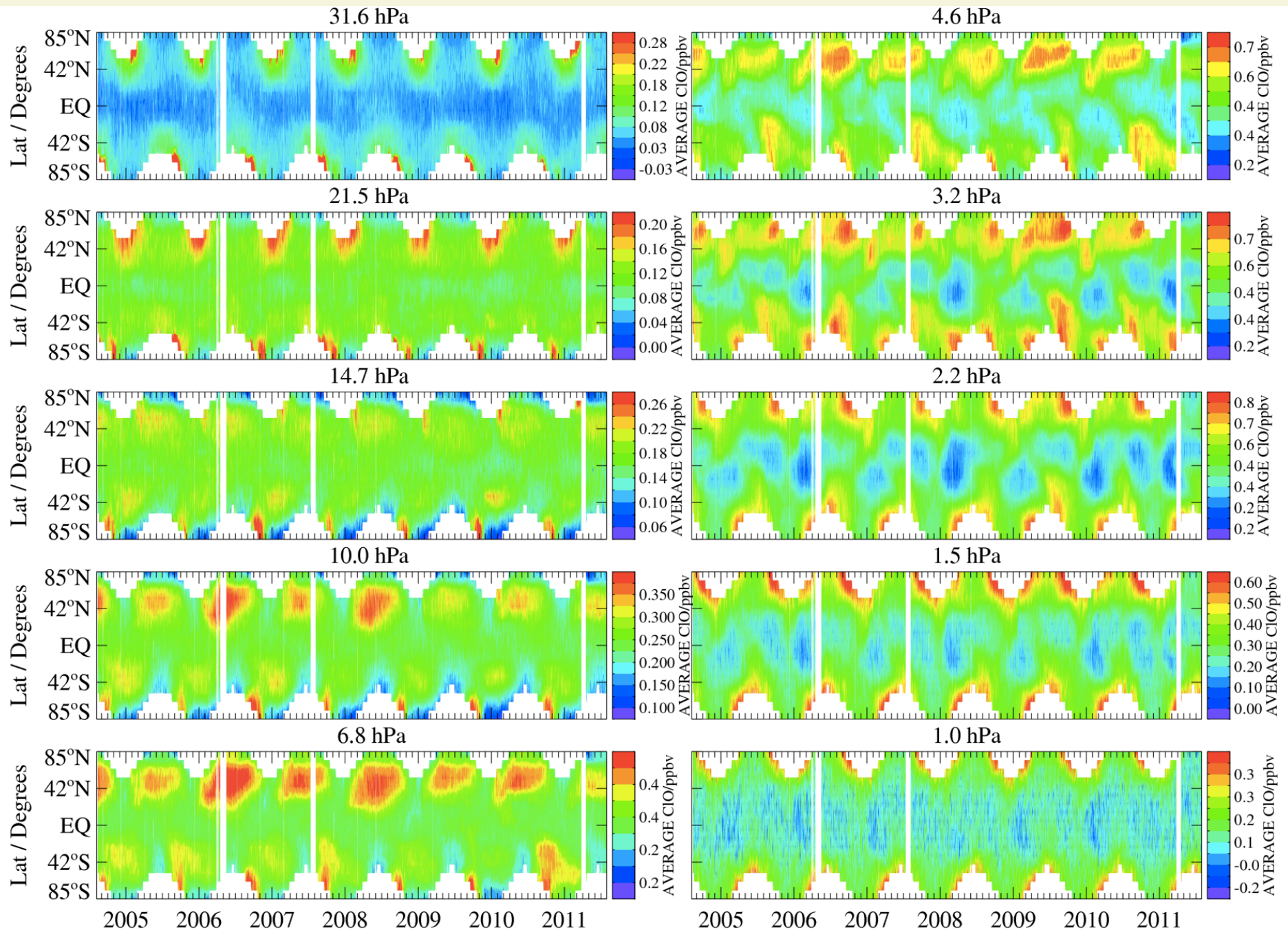


# SZA variation in MLS coverage over 12 months

- We have binned daytime CIO using  $\text{SZA} < 80^\circ$ 
  - also bin nighttime CIO datasets for  $\text{SZA} > 100^\circ$  (+ 2 twilight cases)
- SZA coverage (x axis) for all months (y axis) in NH lats [see below]



# Overview of daytime Aura MLS CIO: 32 to 1 hPa (Aug. 2004 – Aug. 2011)



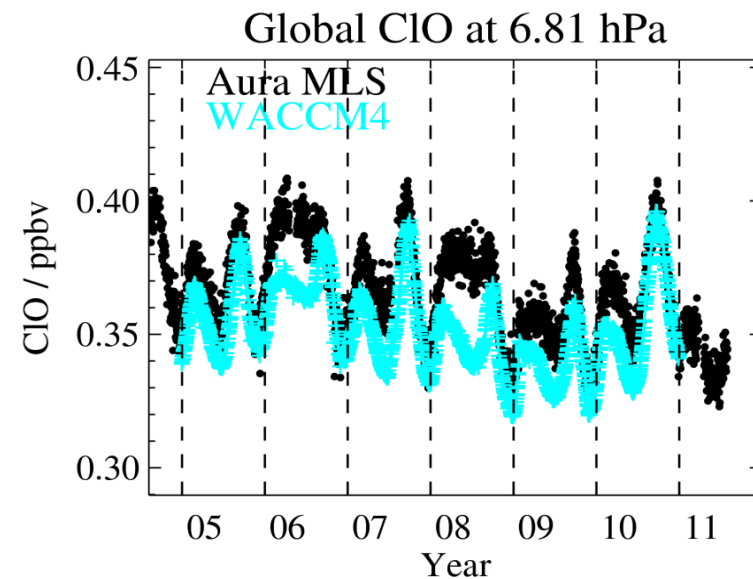
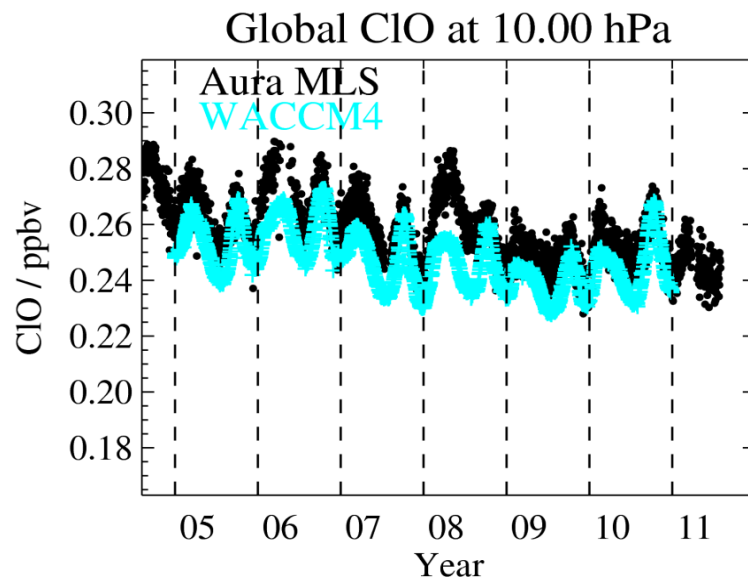
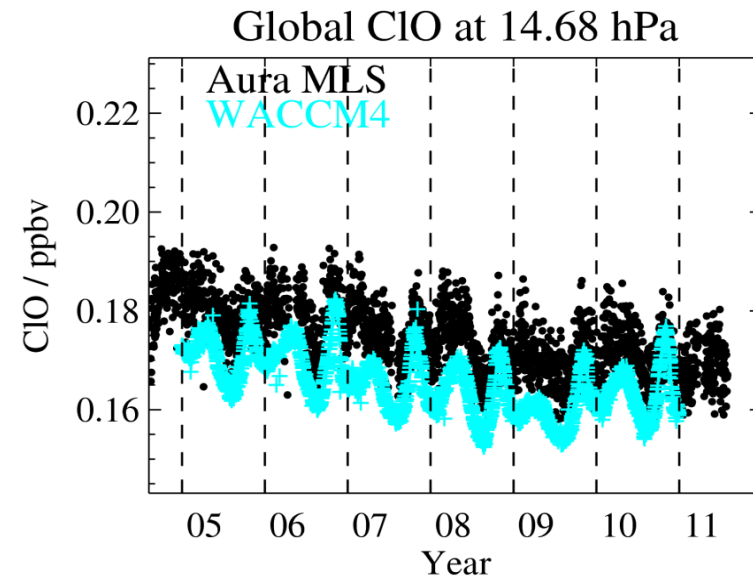
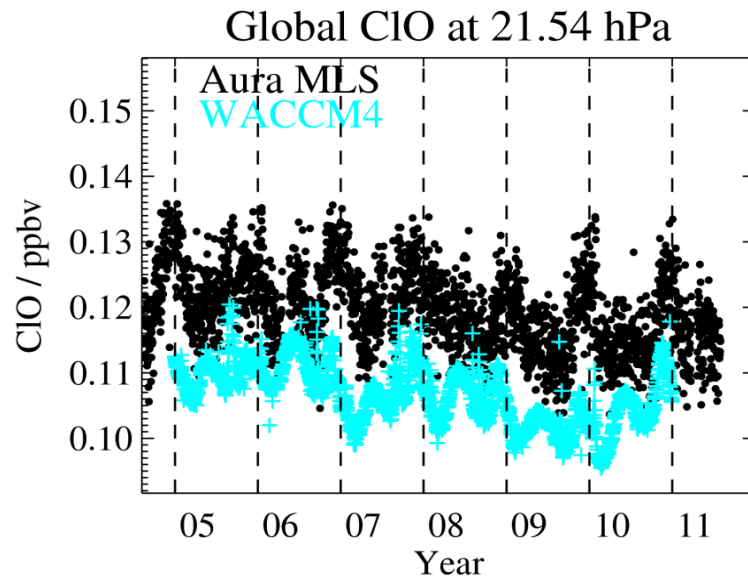


# Specified Dynamics (SD) WACCM4/GEOS-5 Model runs

- **Chemistry** (122 species; 380 chem. reactions; time step is 30 min.)
  - Represents chemical processes from troposphere through lower thermosphere (Ox, HOx, NOx, ClOx, and BrOx chemical families; CH<sub>4</sub>, NMHC and oxidation products)
  - CFCs, HCFCs, and halons based on surface VMRs → **changing Cl**
- **Dynamics / Transport:**
  - Meteorological fields are from the NASA GMAO [GEOS5].
    - 0.5°x 0.66°, 72 levels (up to 80 km)  
→ 1.9°x 2.5° [WACCM4 resolution]
  - Vertical: 88 levels (up to 140 km)
  - Cross over from SD to fully interactive dynamics above ~50km
  - Nudge the model at every time step [→ “follows” GEOS-5]
- **Simulation period:**
  - Showing: 1 Jan 2005 through end of 2010
  - Output consistent with Aura MLS profile locations & local times
  - **Daytime ClO used here:** binned using SZA < 80°
    - as defined for zonal mean daytime Aura MLS ClO dataset [5°lat. bins]

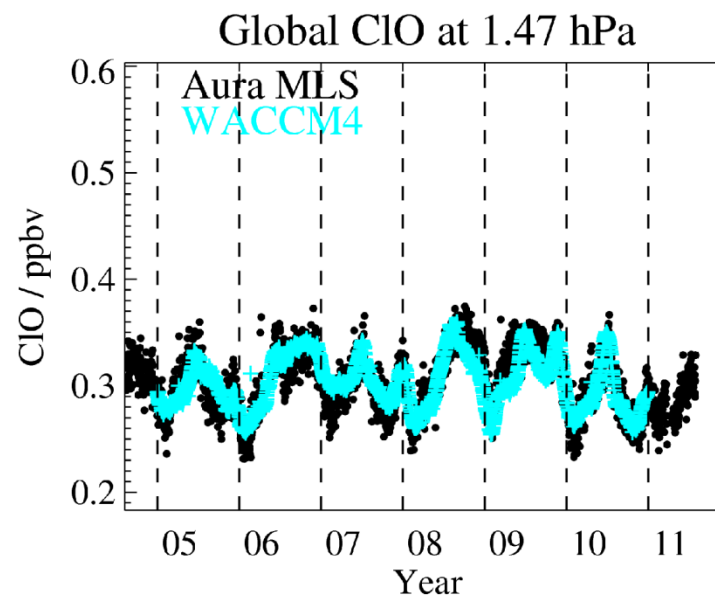
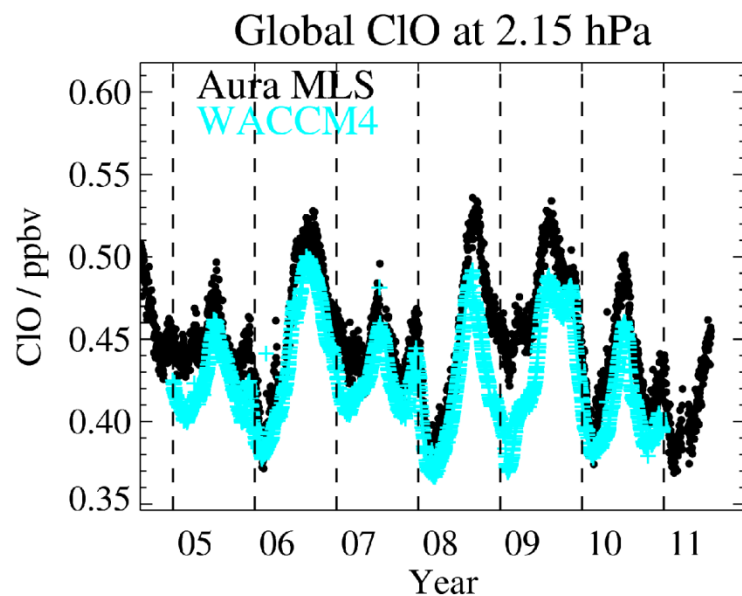
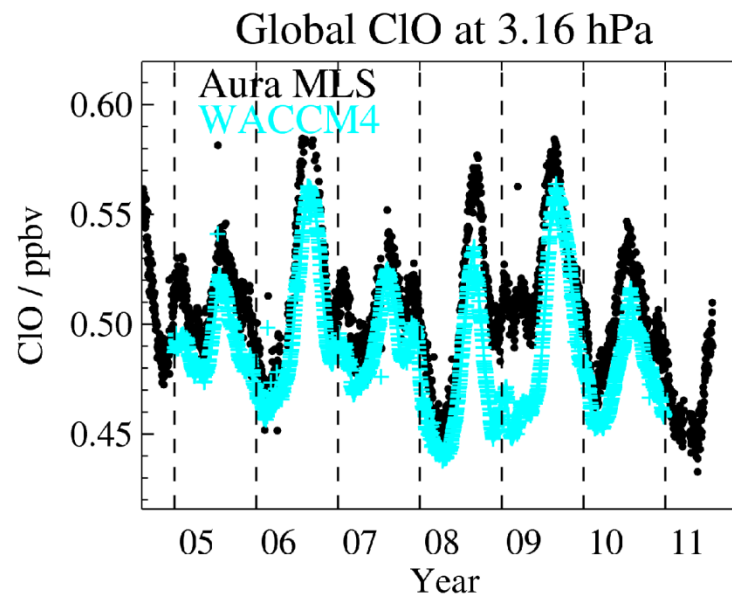
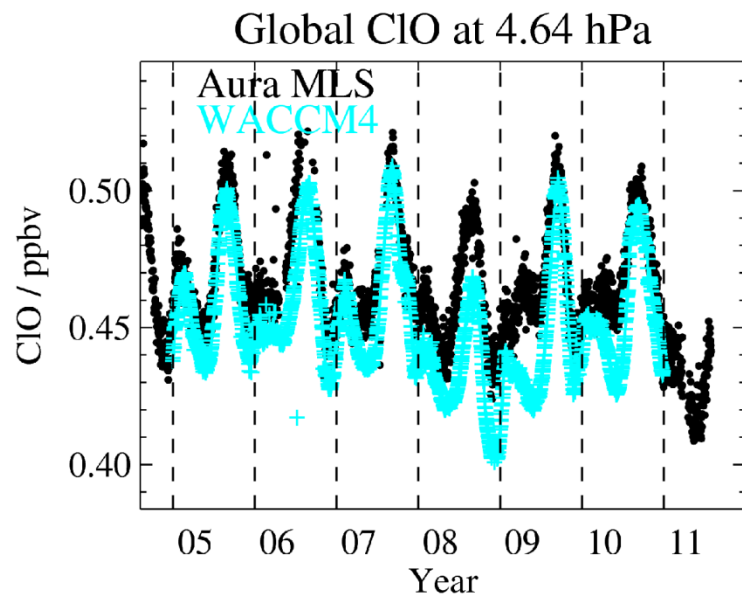
# Aura MLS and SD-WACCM4 daytime ClO time series (22 hPa to 7 hPa)

- Excellent agreement, overall, in these time series



## Aura MLS and SD-WACCM4 daytime ClO time series (4.6 to 1.5 hPa)

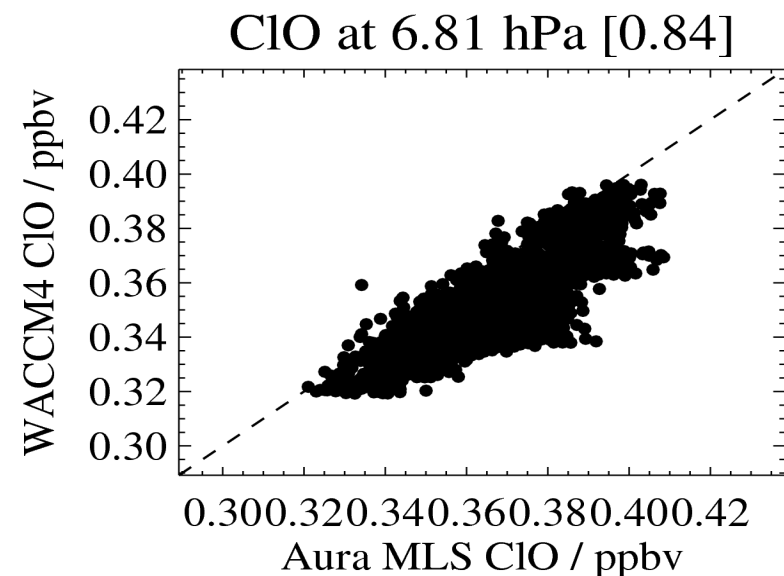
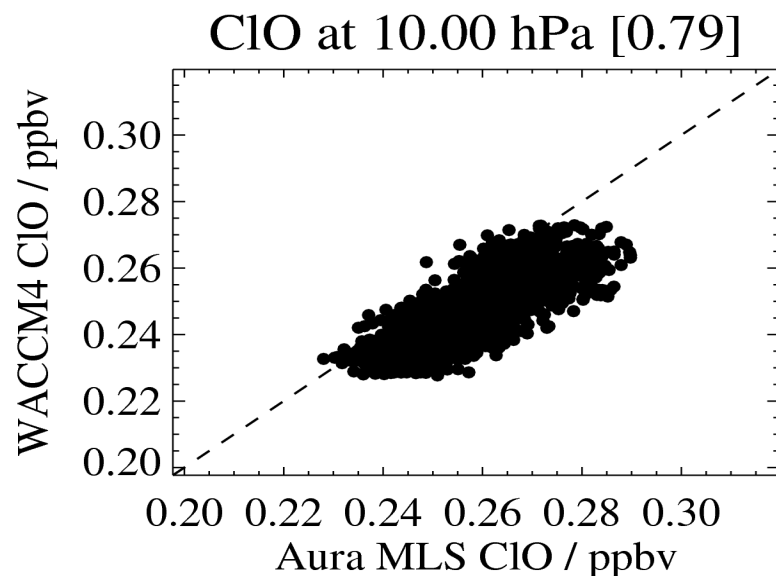
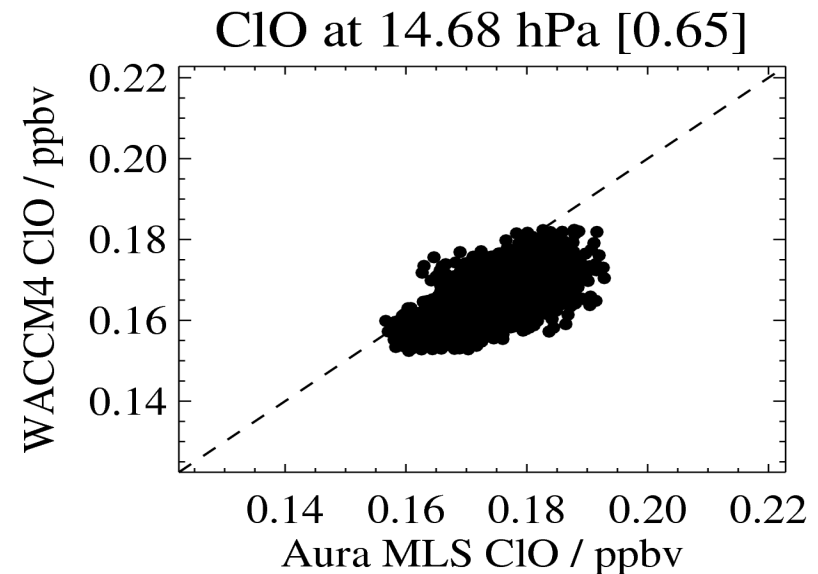
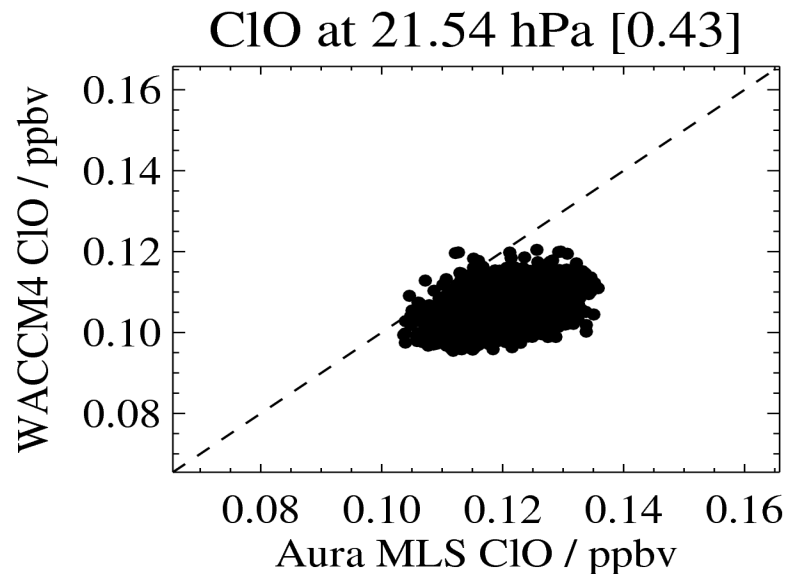
- Excellent agreement, overall, in these time series





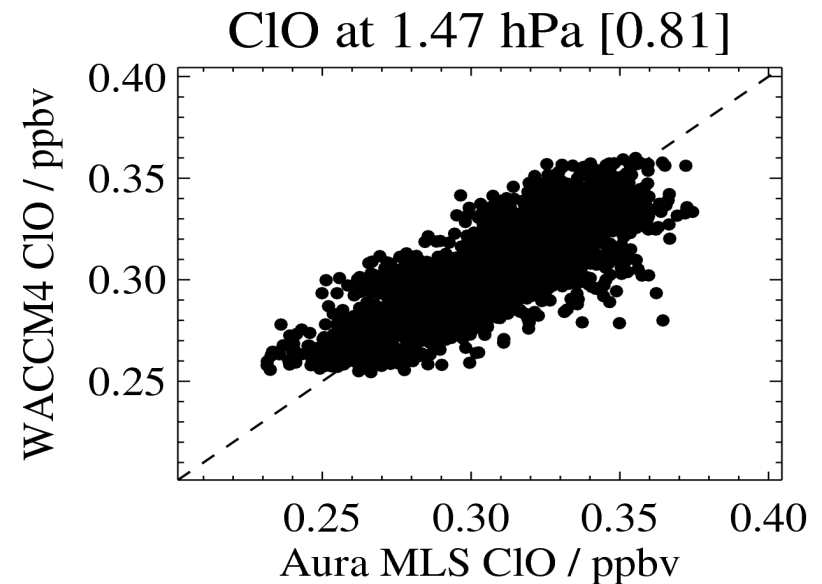
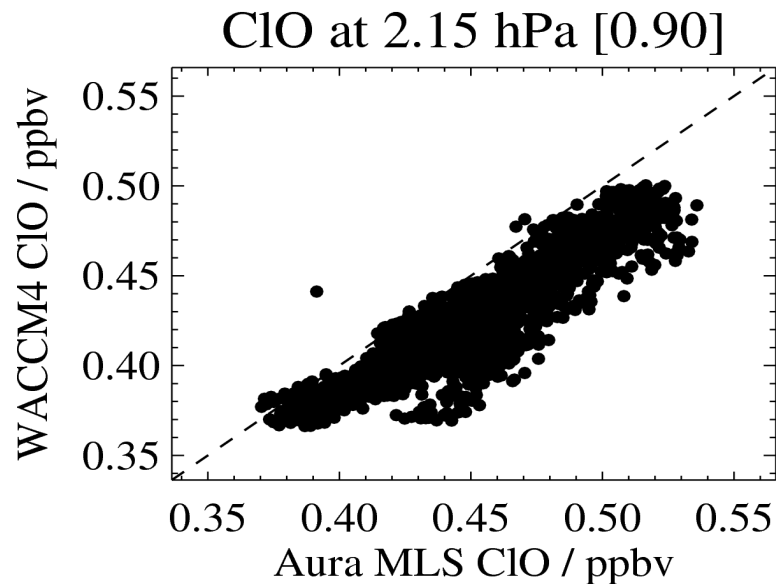
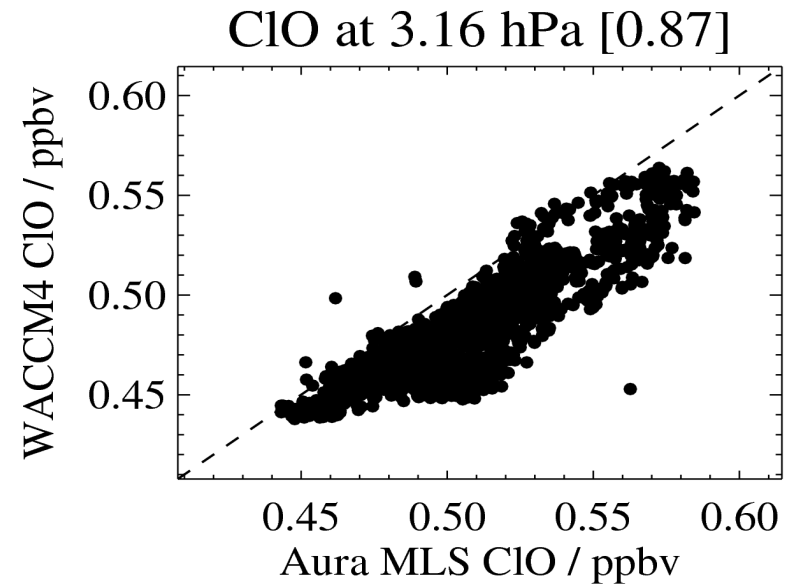
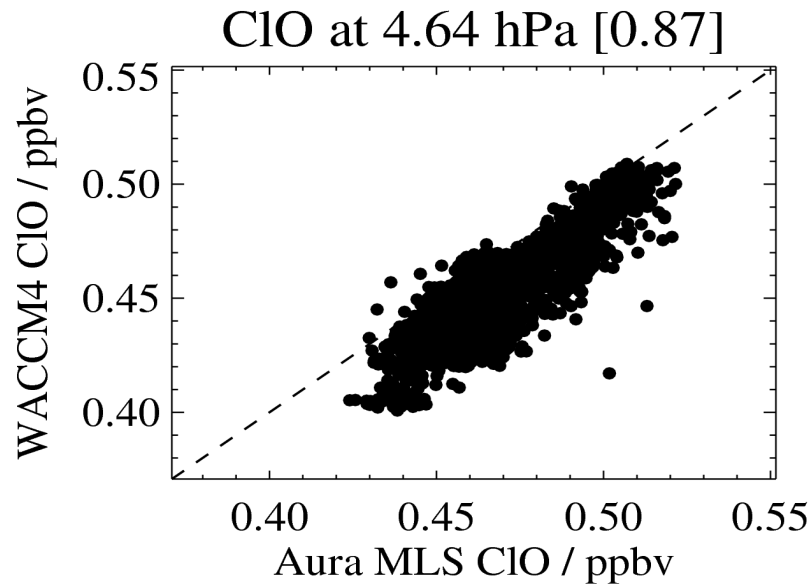
# Daytime ClO: SD-WACCM4 versus Aura MLS (2005-2010)

- High degree of correlation - especially for  $p \leq 10$  hPa
- Model values slightly lower than MLS (but within error bars)



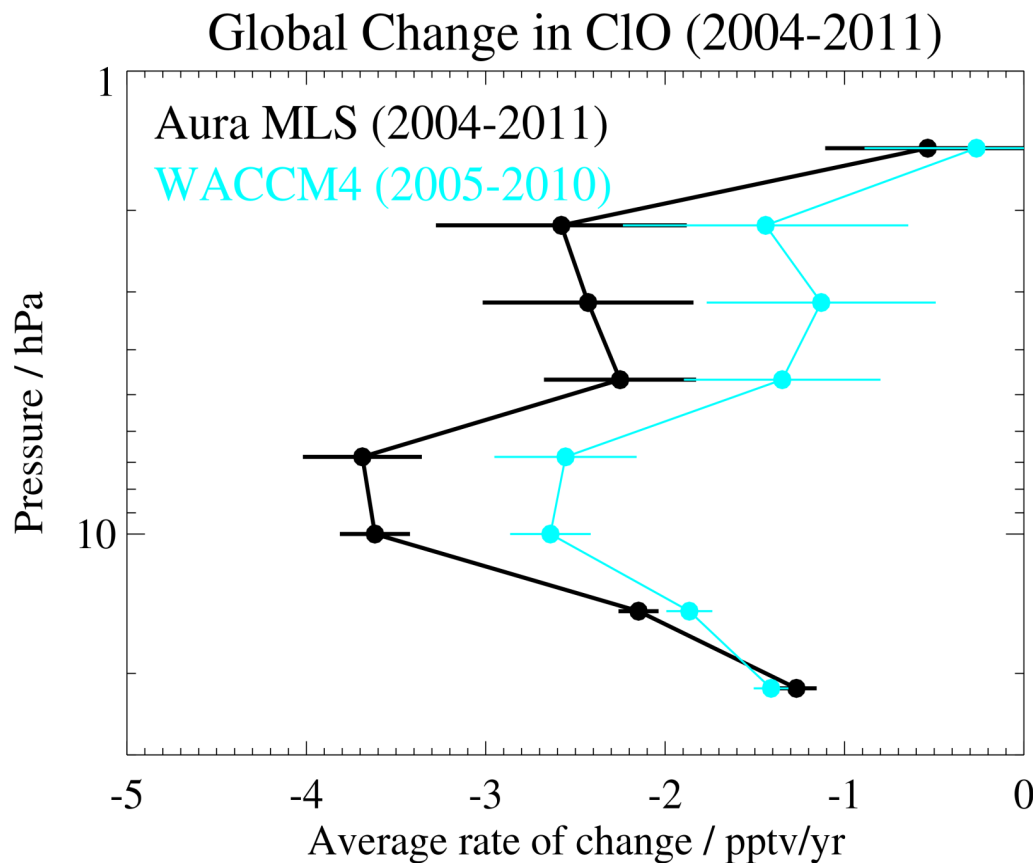
# Daytime ClO: SD-WACCM4 versus Aura MLS (2005-2010)

- High degree of correlation - especially for  $p \leq 10$  hPa
- Model values slightly lower than MLS (but within error bars)



# Rate of decrease for daytime ClO: SD-WACCM4 vs Aura MLS

- Preliminary results for average rate of change in global ClO show fairly good agreement (values and vertical distribution),  
> model ClO appears to decrease slightly slower than implied by MLS
- However, these numbers are subject to revision in terms of residual linear rates of change, as seasonal and QBO variations need to be better accounted for  
> additional analyses to follow, using Aug. 2004 to late 2011 model + data

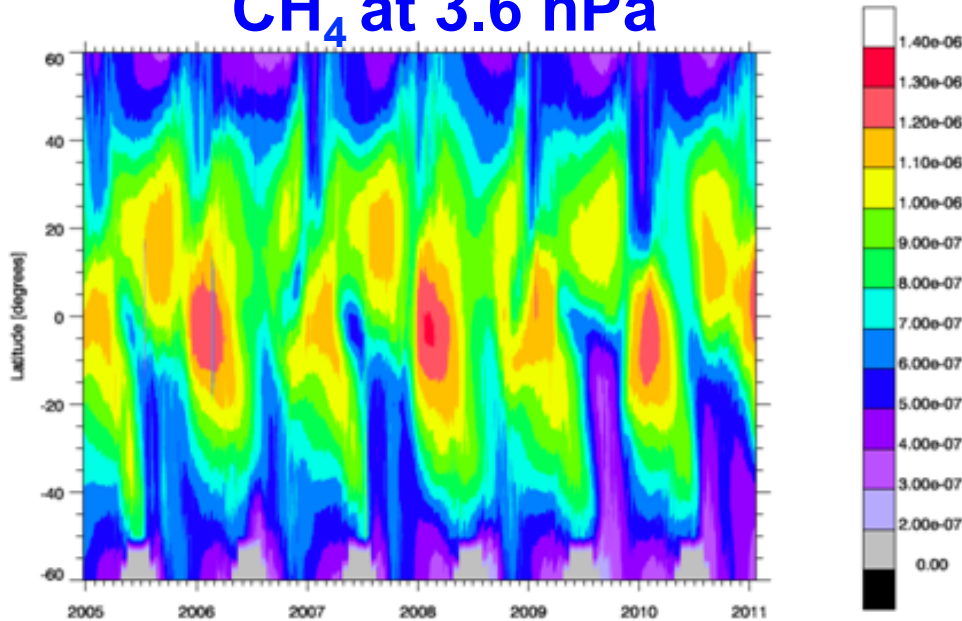


- **Notes:**

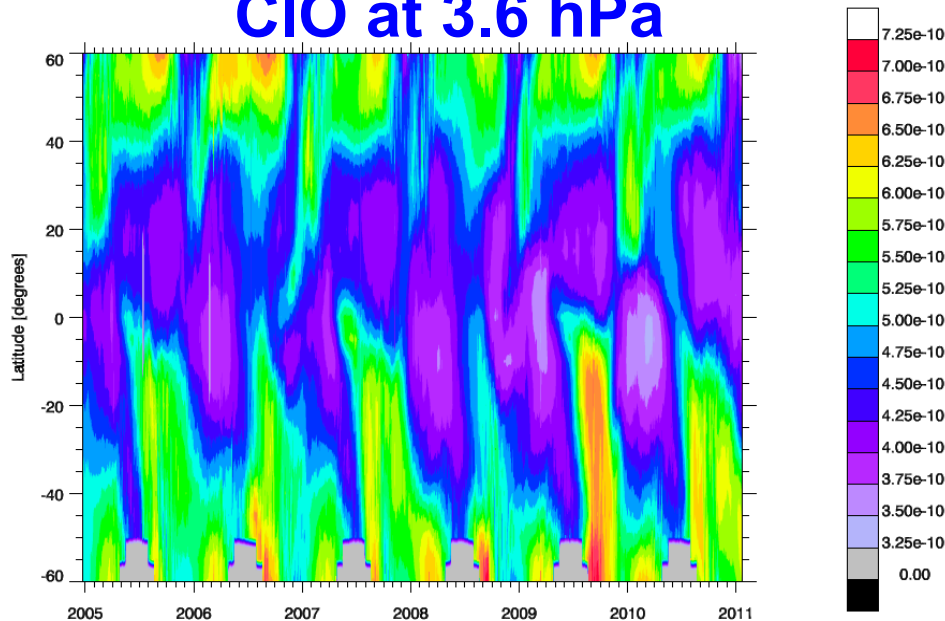
- ClO is a small fraction of Cly and a few pptv/yr for  $d\text{ClO}/dt$  vs 15-25 pptv/yr for  $d\text{Cly}/dt$ .
- ClO also affected by  $\text{CH}_4$ ,  $\text{H}_2\text{O}$ ,...

# SD-WACCM4/GEOS-5 Model runs

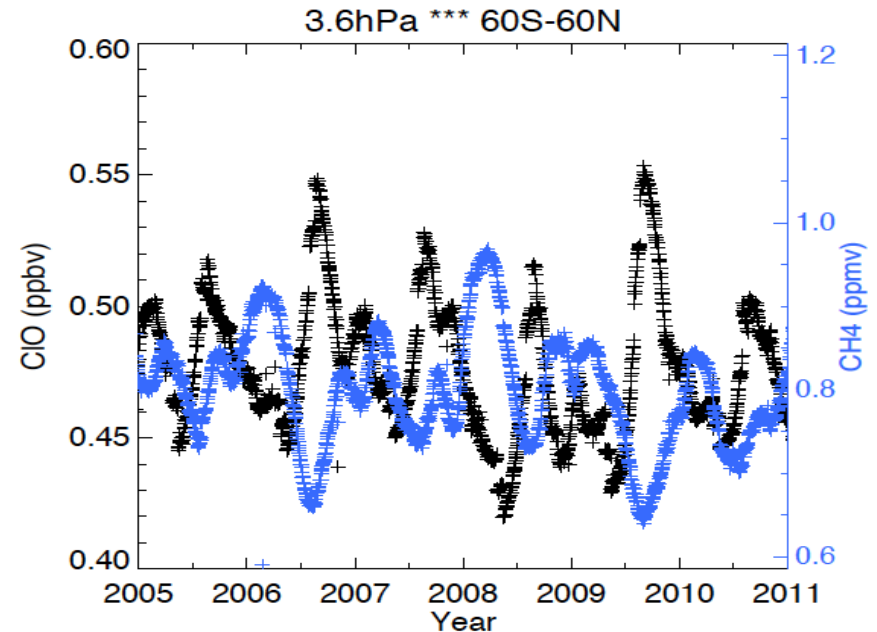
## CH<sub>4</sub> at 3.6 hPa



## CIO at 3.6 hPa



## Anti-correlation between CIO and CH<sub>4</sub>



- Previous papers have highlighted how CH<sub>4</sub> and H<sub>2</sub>O (+ annual, QBO cycles) can impact CIO: e.g., see *Siskind et al. [1998]*, *Froidevaux et al. [2000]*, *Solomon et al. [2000]*, *Nedoluha et al. [2011]*.
- Related investigations to be pursued regarding detailed causes of “long-term” changes in CIO (data & model).

# Summary

- We have performed preliminary analyses of the average rate of change in global daytime mid-to upper stratospheric ClO from Aura MLS (2004-2011).
- The ClO changes (magnitude and vertical distribution) are in overall good agreement with global model results (SD-WACCM4/GEOS5 avg. time series, sampled similarly to the MLS observations).
  - > more detailed analyses are being pursued.
- The observed upper stratospheric ClO decreases do appear to stem from global surface Cl decreases (and international restrictions on Cl source gases).
- Changes in ClO are not as closely tied to total chlorine as upper stratospheric HCl (as ClO is also influenced by CH<sub>4</sub>, H<sub>2</sub>O, etc...).
- However, long-term changes in active chlorine reflect more directly (than HCl) on O<sub>3</sub> depletion and recovery.